ZINC-ORE MINING AND MILLING METHODS, PIQUETTE MINING AND MILLING CO., TENNYSON, WIS.

BY W. A. GROSH AND T. A. EVANS, JR.

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ZINC-ORE MINING AND MILLING METHODS, PIQUETTE MINING AND MILLING CO., TENNYSON, WIS.[1]

by

W. A. Grosh[2] and T. A. Evans, Jr.[3]

SUMMARY

The Piquette Mining and Milling Co. operates a zinc mine and concentrating mill in the Upper Mississippi Valley zinc-lead district near Tennyson, Wis. The principal ore mineral is zinc sulfide, which occurs in limestones and dolomites of the Decorah formation.

Exploration in the district is by churn drilling from the surface. An adit at the base of the ore zone provides access to the mine. A room-and-pillar mining method with irregular pillars is used. Drilling is done with Jumbo-mounted drills. The broken ore is loaded by crawler-mounted front-end loaders into diesel-powered trucks for haulage direct to the mill.

The ore is crushed and partly concentrated in a jig mill, where a lead concentrate, a rough zinc concentrate, and a jig tailing are produced. The zinc concentrate is further reduced in size, and a final concentrate made in a flotation mill. The final products are zinc concentrate, lead concentrate, and a jig tailing. The latter is sold locally for road metal or in some instances for agricultural lime.

INTRODUCTION

This paper is one of a series of publications being issued by the Federal Bureau of Mines on production data of mining and milling operations in the United States. A similar series of publications from 1928 to 1939 contributed substantially to the mineral-industry literature.

This report describes mining and milling methods at a small mine in the Upper Mississippi Valley zinc-lead district. The Piquette Mining and Milling Co. is a joint venture of the American Zinc, Lead, and Smelting Co. and the Piquette Mining Co. The operation was considered of general interest because it was one of the most recent developments in the district and offered an opportunity to present data about an area on which there has been little recent literature.

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HISTORY OF MINE

Numerous shallow lead pits in the Tennyson area give evidence of early lead mining. Few records of this production are available.

Zinc ore was mined intermittently during 1902-18 from several mines east and northeast of Tennyson. According to available records, the greatest production was attained during 1915-18. Mining in the area remained dormant until 1930, when some shaft sinking was done on the Pleumer farm. In 1937 mining was resumed in the area and continued sporadically until about 1940.

During the Second World War, interest in the area revived, and some exploration drilling was done by Francis Piquette of the Piquette Mining Co. In 1945 the Federal Bureau of Mines conducted an exploration program on several properties in and near the village of Tennyson that indicated a zinc ore body.[4]

There was no mining activity until 1950, when the Piquette Mining Co. resumed drilling in the area east of the village of Tennyson. In August 1952 the Piquette Mining and Milling Co. was formed. Early in 1953 the Piquette No. 2 adit (fig. 1) was opened, and two crosscuts across the strike of the ore were driven to obtain samples for testing purposes. Work was recessed in January 1954 while a mill was designed. Construction was begun in August 1954 and the mill operation on May 7, 1955. The mine and mill have been operated almost continuously since that time.

GEOLOGY

The Upper Mississippi Valley zinc-lead district lies within the Driftless Area of Wisconsin, where only remnants of glacial drift of pre-Wisconsin age remain. Pleistocene deposits occur in the valleys of principal rivers, and deposits of loess of pre-Wisconsin age occur on the bluffs in a belt several miles wide along both sides of the Mississippi River.

Figure 2 is a generalized stratigraphic column of the district. Commercial deposits occur in the Galena, Decorah, and Platteville formations of Middle Ordovician age, which are composed largely of dolomites but include some limestone and shales.

Bedrock in the vicinity of Tennyson is generally either the Galena or Decorah formation.

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[4] Apell, G. A., Zinc Deposits of the Tennyson District, Grant County, Wis.: Bureau of Mines Rept. of Investigations 4083, 1947, 13 pp.

Type of Deposit

Ore minerals are sphalerite and galena associated with pyrite, marcasite, and vein calcite. The principal zinc-ore bodies are in the "pitch and flat" type of deposit common to the area. The pitches are mineralized, inclined fractures crossing the bedding planes at steep angles, and the flats are mineralized bedding-plane fractures or openings. The ore bodies are associated with structural troughs apparently caused by solution and subsequent collapse of the limestone formations. The ore minerals occur as vein-type fillings and replacements along fractures and in bedding-plane openings; also as fillings in solution cavities and as disseminations in favorable beds or horizons.

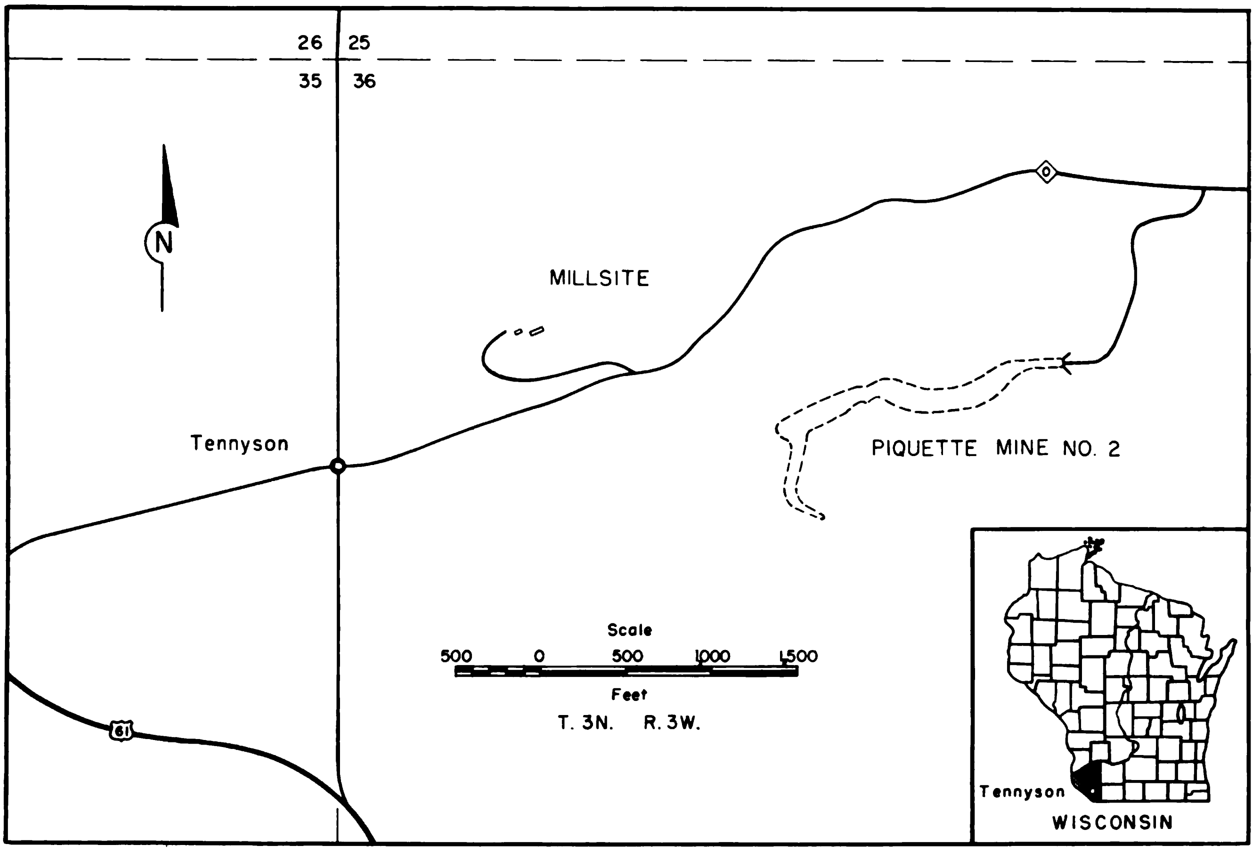
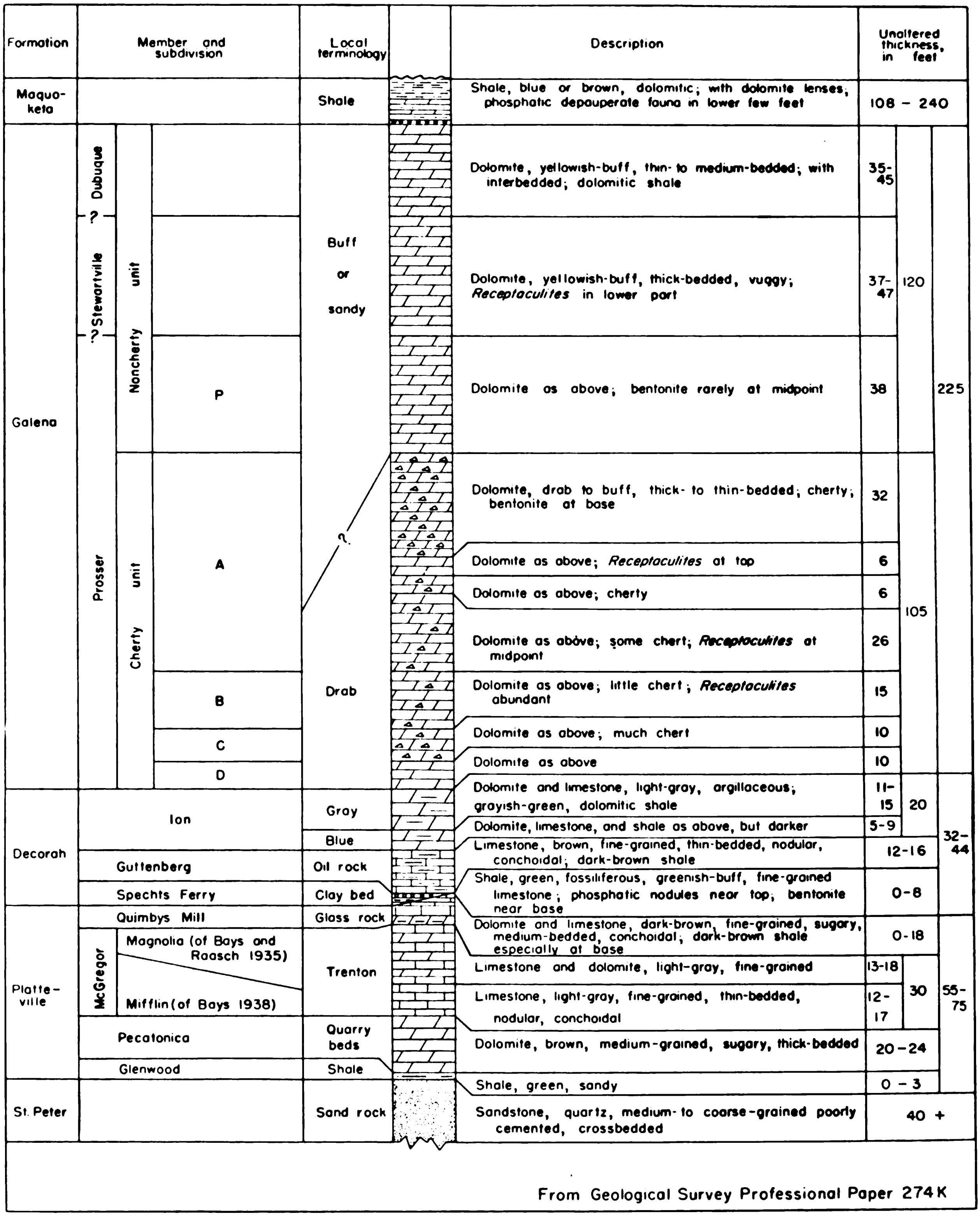


FIGURE 1. - Location Map of Piquette No. 2 Mine, Grant County, Wis.

In addition to the pitch and flat type of deposit there is some joint-controlled ore in gash veins, locally called "crevice" deposits. In these the ore occurs as filling in narrow vertical joints and expands in pods at favorable beds or horizons. These veins were the principal source of ore before 1860, when production from the district was largely lead ore. The gash veins have the same principal minerals, but galena rather than sphalerite is the predominant ore mineral. The gash veins generally occur in the Galena dolomite above the main horizon of the principal zinc-ore bodies.



Formation	Member and subdivision			Local terminology	Description	Unaltered thickness, in feet		
Maquo-keta				Shale	Shale, blue or brown, dolomitic; with dolomite lenses; phosphatic depauperate fauna in lower few feet	108 - 240		
Galena	Dubuque	Noncherty unit		Buff or sandy	Dolomite, yellowish-buff, thin- to medium-bedded; with interbedded; dolomitic shale	35-45	120	225
	? Stewartville ?				Dolomite, yellowish-buff, thick-bedded, vuggy; *Receptaculites* in lower part	37-47		
	Prosser		P		Dolomite as above; bentonite rarely at midpoint	38		
		Cherty unit	A	?	Dolomite, drab to buff, thick- to thin-bedded; cherty; bentonite at base	32	105	
					Dolomite as above; *Receptaculites* at top	6		
					Dolomite as above; cherty	6		
					Dolomite as above; some chert; *Receptaculites* at midpoint	26		
			B	Drab	Dolomite as above; little chert; *Receptaculites* abundant	15		
			C		Dolomite as above; much chert	10		
			D		Dolomite as above	10		
Decorah	Ion			Gray	Dolomite and limestone, light-gray, argillaceous; grayish-green, dolomitic shale	11-15	20	32-44
				Blue	Dolomite, limestone, and shale as above, but darker	5-9		
	Guttenberg			Oil rock	Limestone, brown, fine-grained, thin-bedded, nodular, conchoidal; dark-brown shale	12-16		
	Spechts Ferry			Clay bed	Shale, green, fossiliferous, greenish-buff, fine-grained limestone; phosphatic nodules near top; bentonite near base	0-8		
Platte-ville	Quimbys Mill			Glass rock	Dolomite and limestone, dark-brown, fine-grained, sugary, medium-bedded, conchoidal; dark-brown shale especially at base	0-18		55-75
	McGregor	Magnolia (of Bays and Raasch 1935)		Trenton	Limestone and dolomite, light-gray, fine-grained	13-18	30	
		Mifflin (of Bays 1938)			Limestone, light-gray, fine-grained, thin-bedded, nodular, conchoidal	12-17		
	Pecatonica			Quarry beds	Dolomite, brown, medium-grained, sugary, thick-bedded	20-24		
	Glenwood			Shale	Shale, green, sandy	0 - 3		
St. Peter				Sand rock	Sandstone, quartz, medium- to coarse-grained poorly cemented, crossbedded	40 +		

From Geological Survey Professional Paper 274K

FIGURE 2. - Stratigraphic Column of Platteville, Decorah, and Galena Strata in Lead-Zinc District.

A more detailed discussion of the geology and formation of the ore bodies has been published by the Federal Geological Survey.[5]

The Piquette No. 2 ore body has a series of steeply dipping fracture zones that have been mineralized. These fractures strike roughly east-west and dip southward. They produce a series of highly mineralized zones interfaced with relatively barren material.

The limestones and dolomites of the enclosing formation are generally strong and stand well over moderate distances; however, the faulting, fracturing, and solution alteration in the ore bodies reduce the natural strength of the formations. Usually the walls and backs of a mining opening are formed by relatively unaltered strata.

EXPLORATION

Exploration is conducted exclusively by churn drilling from the surface. No underground exploration work is done, and all the headings are driven as part of the mining system.

The general plan of the exploration program is to cross the mineral trend with cross sections of holes spaced 25 or more feet apart. Cross sections are spaced along the strike of the mineral trend 100 feet or more apart. The spacing of holes on the cross sections and of sections along the strike of the deposit depends on the size and configuration of the deposit. In the larger, more regular deposits the holes and cross sections can be spaced farther apart in the exploratory program.

Six-inch churn-drill holes are used for exploration work. The surface material usually contains enough clay so that casing is not generally required. Sampling intervals are limited to 5 feet or less in overburden and nonmineralized formations. The sludges are collected separately for each 5-foot interval. When appreciable mineralization indicates an ore body, the sample interval is reduced to 2-1/2 feet.

When the hole has reached the required depth for the sample interval, the drill tools are pulled, and the bailer is run in the hole. Flat-valve bailers are used, and the bailer is churned up and down in the hole to mix the heavy material at the bottom. All the bailings from one interval are dumped into a tub and mixed. A small amount of water is usually added to expedite settling of the solids. One or two shovelfuls of the cuttings are piled on the ground for inspection and panning; the remaining cuttings are discarded. From this examination the stratigraphic horizon is determined, and the quantities of iron, lead, zinc sulfides, and zinc carbonates are estimated. If enough mineralization is found by examination, part of the pile is taken for analysis. When significant amounts of carbonate-ore minerals are observed in panning, the metal content as carbonate is also determined by chemical analysis. Drill logs of the holes are prepared showing collar elevation, depth of overburden, stratigraphic horizons, estimated mineralization, and chemical analyses for lead, zinc, and iron.

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[5] Heyl, Allan V., Lyons, Erwin J., Agnew, Allen F., and Behre, Charles H., Jr., Zinc-Lead-Copper Resources and General Geology of the Upper Mississippi Valley District: Geol. Survey Bull. 1015-G, 1955, pp. 227-245.

This method of sampling, with some minor modifications, has been used throughout the district by most companies for many years. Early in the drilling program the company tested its sampling method by running comparison analyses. Piles from one hole were sampled in the usual manner, and the entire remaining portion of the sample interval was also shipped for analysis. The two analyses agreed within limits that the company considered satisfactory; however, it is recognized that the utmost care must be taken in drilling, bailing the hole, and sampling the piles to obtain dependable results. With all precautions taken, it is still essential that the person logging the hole examine the cuttings carefully and review analyses critically for evidences of caving in the hole, which might cause salting or contamination of the samples.

MINE DEVELOPMENT AND SELECTION OF EQUIPMENT

Exploration drilling indicated a flat-lying ore body of considerable lateral extent. Indicated dimensions of the ore body in the planning stage were of the magnitude of over 1,000 feet long and 100 to 200 feet wide, with the ore zone 15 or more feet high throughout much of the ore body. On the basis of information obtained by drilling, plans were made to mine the ore body by the room-and-pillar method used successfully for similar ore bodies in the district.

The Piquette No. 2 ore body on the Pleumer farm was developed by an adit in the side of a hill at the elevation of the lowest principal ore zone. The adit is approximately 12 feet in height and ranges from 15 to 20 feet in width; it was driven horizontally about 258 feet before the edge of the ore body was reached (fig. 3). The mine floor, in the Decorah formation, provides a solid roadbed for operating trackless equipment.

Before the mill was completed and regular production had begun, the adit was continued as a drift along the ore body, and several rooms were turned off. Further mine development has been carried as an integral part of the mining operation.

Pneumatic-tired haulage equipment met the requirements of mobility, flexibility in relation to rapidly changing loading points, and long haul at relatively high speed. In selecting the type of unit, short turning radius, low maintenance, and ruggedness were of primary importance. Several operators in the district were using Koehring Dumptors under similar conditions. These machines, with a turning-clearance radius of 20 feet 8 inches, a height of 8 feet 9-1/2 inches, a load capacity of 8-1/4 tons, and a maximum speed of 17.12 m.p.h., were chosen as the most suitable for the conditions.

Crawler-mounted front-end loaders were chosen as the loading device. They are mobile, with a short turning radius, and have the ability to enter areas of moderately low back and load material out to a place of higher back for dumping into trucks. The ability to enter low areas reduces the amount of overbreak or dilution necessary to recover the ore in areas where the mineralization is less than the minimum height for haulage equipment. Allis Chalmers HDSG end loaders with 1-yard buckets were used.

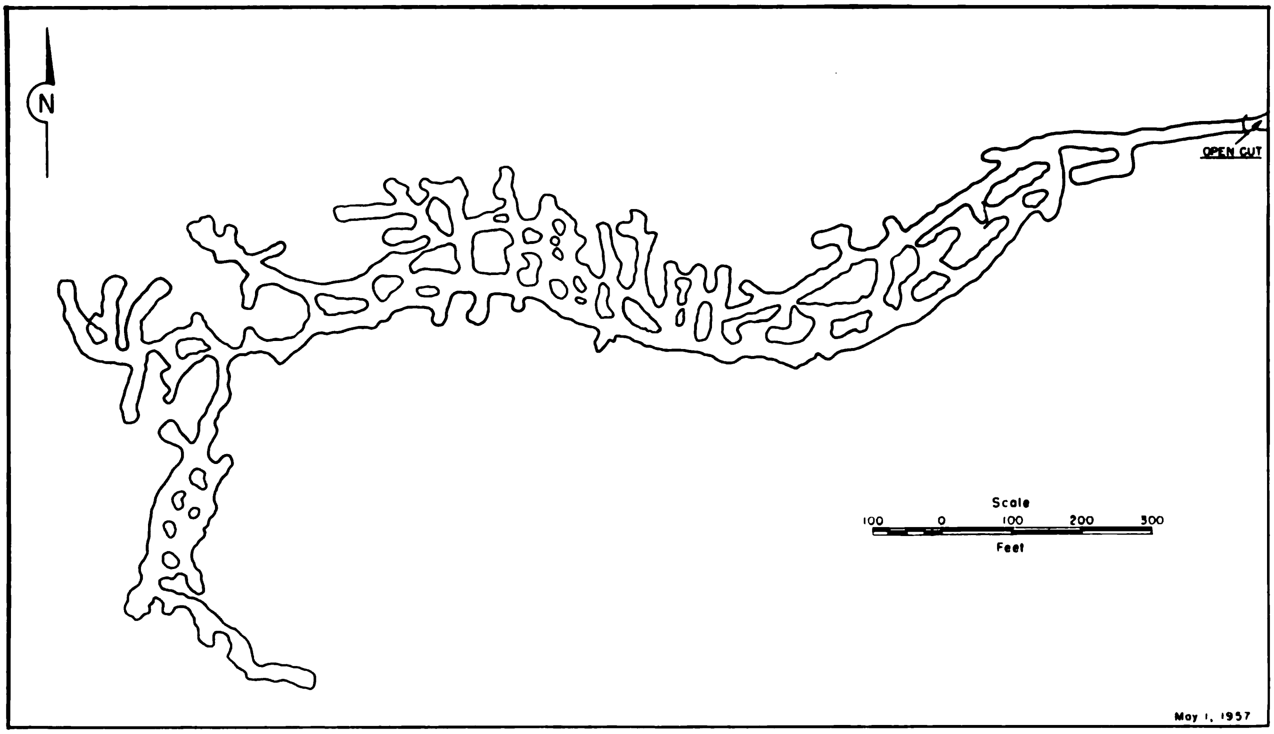

FIGURE 3. - Plan Map, Piquette No. 2 Mine.

MINING

The mining method, as classed by the Federal Bureau of Mines, is open stope, with irregular pillar support. The location and size of the pillars are determined by the mineralization or grade and condition of the rock. Generally, the ground stands well, and the limestone forms a good back. No timber or rock bolting is used. Every effort is made to have the pillars in lean ground. Ultimately, many of the pillars shown in figure 3 will be robbed after mining has reached the limits of the ore body.

Drilling is done with a Joy Jumbo, having 2 jibs with 12-foot feed, mounted on a diesel-powered Allis Chalmers D5 tractor. The company also has a single Joy boom mounted on a modified Reo truck. This is used to trim pillars and drill slabbing rounds. A Jackleg is also available for drilling holes in places not suitable for Jumbo operation.

One-inch hexagonal steel is used with carbide-insert chisel bits, manufactured by Sandvik Cormant Co., Sweden. Bits, 1-5/8 inches when new, are resharpened by grinding until a minimum size of 1-3/8 inches is reached; then they are discarded. Drill footage for each bit varies, but the company occasionally gets up to 2,000 feet per bit. No records are kept as to the number of times a bit is sharpened. Sharpening is done at the mine with a 4,000-r.p.m. grinding wheel manufactured by Atlas Diesel Co., Sweden.

Steel costs $25.50 per 10-foot length. The estimated cost of steel per ton of rock is 4 cents, or 1.8 cents per foot of hole drilled.

The standard round for a 20-foot-wide face is illustrated in figure 4. This round was chosen after some experimenting with various types of rounds during the early development of the mine, and gives satisfactory results under most conditions. It is drilled with the two-jib Jumbo. If the face is wider than 20 feet, 4 extra holes are added on each side of the round, as indicated in the sketch.

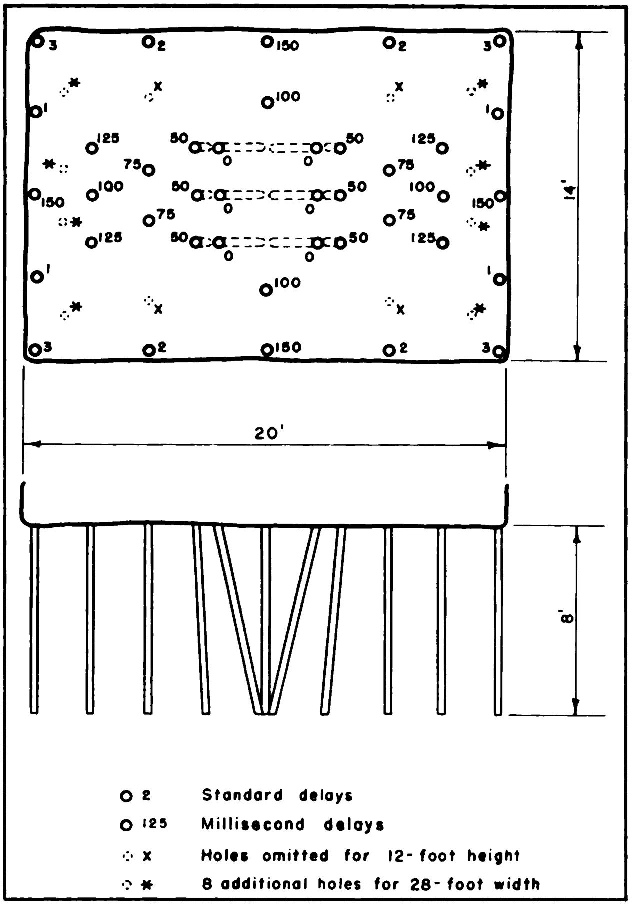
3
2
150
100
1
125
75
50
0
20'
14'
8'
O 2 Standard delays
O 125 Millisecond delays
x Holes omitted for 12-foot height
* 8 additional holes for 28-foot width

FIGURE 4. - Diagram of Typical Drill Round.

Both millisecond-delay and standard-delay blasting caps are used for detonating. Lead wires on caps are 10 feet long and connected in 2 series circuits with an equal number of caps. Both circuits are connected to the power source in parallel. Rounds are shot with a DuPont CD32 Type 1 blasting machine from an underground blasting station 800 to 1,000 feet from the working faces.

During 4 months (May through August 1956) operations were fairly uniform. Drilling and blasting performances were as shown in table 1. Production figures are tonnages of mill feed and essentially the same as total mine production.

The company uses 40-percent gelatin dynamite in 1-1/8-inch sticks, Gelex No. 2 in 1-1/8-inch sticks, and Gelex No. 4 in 1-1/4-inch sticks. The amounts of the three types of dynamite are varied according to the hardness of the ground and the degree of difficulty with which it breaks. Generally, the weaker powder, Gelex No. 4, is used at the rate of 2:1 to the Gelex No. 2 (40-percent dynamite).

Mucking is done with diesel-powered end loaders. The company has 3 Allis Chalmers HD5G end loaders with 1-yard buckets; 2 are used in the mine for loading and the other for cleanup around the mill and for loading tailings.

Three diesel-powered Koehring Dumptors are used for hauling ore from the loading face to the mill. These are 6-yard, with 8-1/4-ton capacity and

4-cylinder GMC diesel engines. One GMC diesel truck with a 4-yard-capacity body and a 3-cylinder engine is also used for haulage.

TABLE 1. - Drilling data

Month	Drill footage per ton	Dynamite, lb./ton	Caps, number per ton	Average production tons/day
May	2.18	0.92	0.23	289
June	2.67	1.22	.26	320
July	2.07	.81	.21	350
August	1.90	.78	.20	357

The trucks are loaded at the face and haul the ore to the mill, a distance of slightly over 1 mile from the adit to the mill hopper. There is a difference in elevation of 176 feet between the floor of the adit and the mill hopper or an overall grade against the load of 2.8 percent. The maximum adverse grade of 7.8 percent extends about 1,250 feet from the county road to the mill hopper.

Little secondary blasting is necessary. The loader has little trouble handling most large rocks left from a blast. Pieces too large to handle are piled on one side. After enough have accumulated, they are drilled and blasted.

Each truckload of ore to the mill is weighed at a scalehouse near the mill. The scale (a 30-ton, 34- by 10-foot Webb platform-type) has a direct-reading dial, which faces the truck. The driver reads the gross weight direct and marks it on a tally sheet carried in the truck.

Summary of Mine Equipment, Power, and Supplies

2 compressors, 350 cu. ft./min. at 125 lb.; 75-hp., 440-v. motors.
2 electric sump pumps, 2-hp., 2-inch discharge.
3 Koehring Dumptors, 6-yard, 4-cylinder, diesel.
1 GMC No. 450 truck, 4-yard, 3-cylinder, diesel.
2 Allis Chalmers HDSG end loaders, 1-yard bucket.
1 Joy Jumbo, 2-jibs, 12-foot feed.
1 Joy boom on Reo truck.
1 Jackleg.
2 IR 3-inch drifters.
3 Joy 2-3/4-inch drifters.
1 Atlas diesel steel-sharpening machine.

Electric power is supplied by the Wisconsin Power & Light Co. Transformer stations are provided at both the mine adit and at the mill. Two 350-cu.-ft.-per minute compressors outside the mine adit, each powered by a 75-horsepower, 440-volt motor, supply compressed air for drilling. Compressed air is carried underground in a 4-inch pipe laid alongside the drift. Power is carried underground at 440 volts, 3-phase, for blowers. Single-phase, 220-volt power is used for sump pumps and floodlights. These lights, on portable stands, are used for illuminating faces during drilling or mucking. The main haulage drift is illuminated with 100-watt, 220-volt light bulbs, spaced about 100 feet apart.

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Ventilation and Drainage

Ventilation is provided by 5 surface fans and 1 underground fan; 3 surface fans are mounted over 12-inch churn-drill holes, and 2 over 6-inch churn-drill holes. Exploration drill holes are used for ventilation wherever possible and enlarged to 12 inches where necessary. Surface-fan installations are temporary, and the fans are moved ahead as the faces are advanced. A large fan is used underground to circulate air in the main haulage drift and prevent the accumulation of exhaust gases.

The surface fans vary in size, capacity, and horsepower. Both exhaust and blower fans are used; they are moved from hole to hole to meet the changing needs as the mine progresses. Because of the large interconnected openings and relatively small extent of the ore body, ventilation is not a difficult problem.

Mine drainage is ample. The adit was driven at the bottom of the major portion of the ore body and drains the mine by gravity. In a few places in the ore body the formations roll, and the ore dips below the drainage grade. In these places it is necessary to create a sump and install a pump.

METHOD OF TREATMENT

The all-steel mill building houses the crushing and screening equipment, and the jigs, grinding, and flotation units.

Operation is continuous 6 days a week; the crushing plant operates 1 shift daily, the jig plant 2, and the flotation mill 3. Minor repairs are made on Sunday. Figure 5 is a flowsheet of the entire concentrating plant.

Crushing

Crushing is performed in 3 stages: Mine-run ore is delivered from the 50-ton mill receiving bin by a steel pan conveyor to a 21- by 40-inch Rogers Blake-type jaw crusher driven by a 75-horsepower electric motor. The product from the crusher goes to a 3- by 8-foot vibrating screen with 1-inch-square openings. Oversize from the screen is crushed in open circuit in a 10- by 36-inch Universal jaw crusher and discharges with the undersize from the screen to a 24-inch-belt bucket elevator having 8- by 8- by 24-inch buckets spaced 20 inches apart. The bucket elevator is operated in closed circuit with a 6- by 8-foot trommel screen and a 51- by 20-inch Rogers roll crusher. The screen has 5/8-inch round openings.

The undersize product from the trommel is sampled by an automatic sampler and deslimed in a 4- by 36-foot Esperanza drag classifier. The oversize from this classifier is discharged onto a 20-inch belt conveyor, which delivers into a 275-ton-capacity jig feedbin. The undersize from the classifier is fed to a 4-foot-square sand cone. Sand from the cone, all plus-65-mesh, is combined with underflow from a 50-foot-diameter Dorr thickener and fed to the ball-mill feedbox. Overflow from the cone flows by gravity to the master drag classifier.

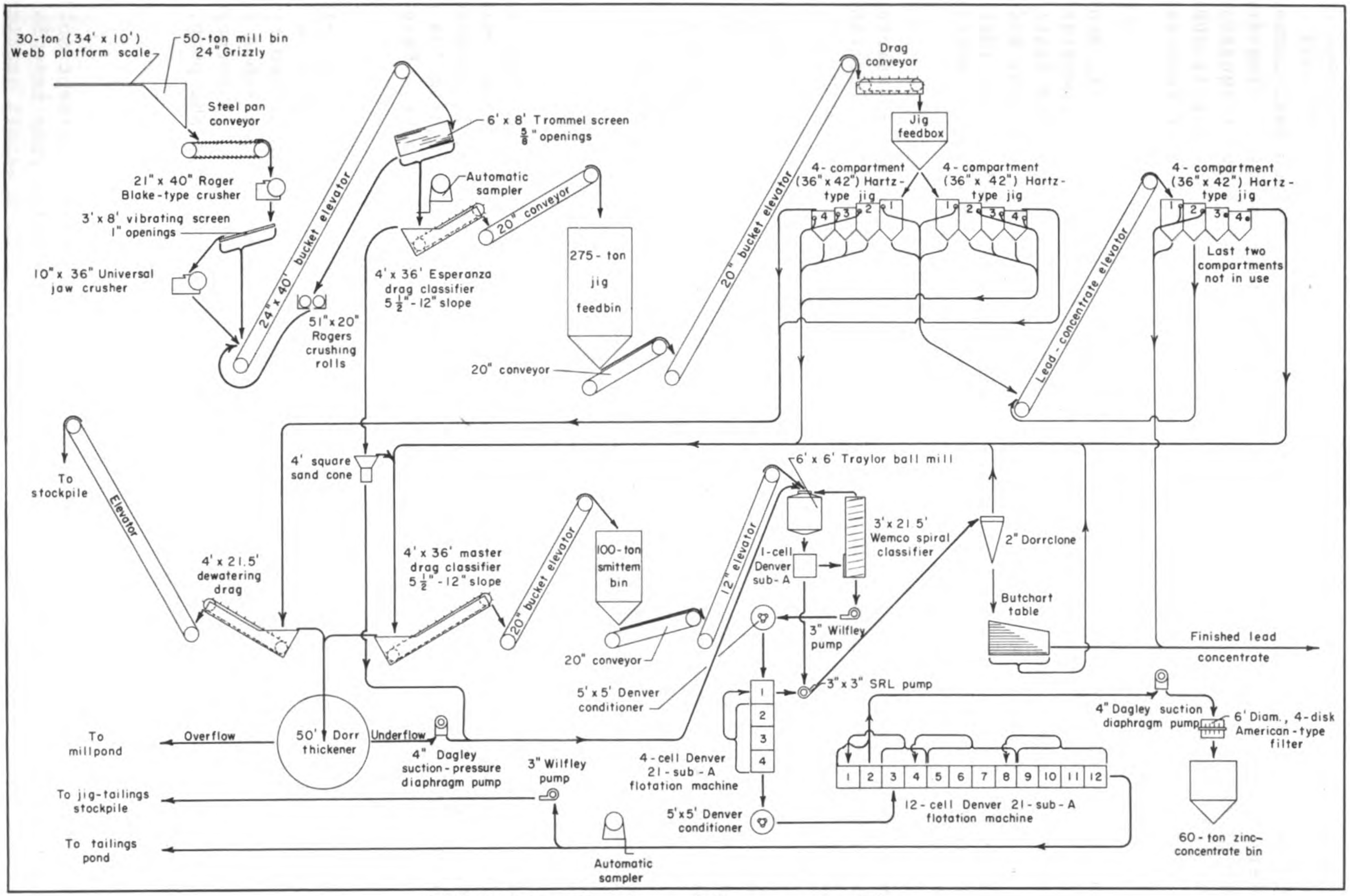
30-ton (34' x 10') Webb platform scale
50-ton mill bin 24" Grizzly
Steel pan conveyor
21" x 40" Roger Blake-type crusher
3' x 8' vibrating screen 1" openings
10" x 36" Universal jaw crusher
24" x 40" bucket elevator
6' x 8' Trommel screen 5/8" openings
Automatic sampler
51" x 20" Rogers crushing rolls
4' x 36' Esperanza drag classifier 5 1/2" - 12" slope
20" conveyor
275-ton jig feedbin
20" conveyor
20" bucket elevator
Drag conveyor
Jig feedbox
4-compartment (36" x 42") Hartz-type jig
4-compartment (36" x 42") Hartz-type jig
4-compartment (36" x 42") Hartz-type jig
Last two compartments not in use
Lead-concentrate elevator
To stockpile
Elevator
4' x 21.5' dewatering drag
4' square sand cone
4' x 36' master drag classifier 5 1/2" - 12" slope
20" bucket elevator
100-ton smittem bin
20" conveyor
12" elevator
6' x 6' Traylor ball mill
3' x 21.5' Wemco spiral classifier
1-cell Denver sub-A
3" Wilfley pump
2" Dorrclone
Butchart table
Finished lead concentrate
5' x 5' Denver conditioner
3" x 3" SRL pump
4" Dagley suction diaphragm pump
6' Diam., 4-disk American-type filter
To millpond
Overflow
50' Dorr thickener
Underflow
4" Dagley suction-pressure diaphragm pump
3" Wilfley pump
4-cell Denver 21-sub-A flotation machine
12-cell Denver 21-sub-A flotation machine
5' x 5' Denver conditioner
60-ton zinc-concentrate bin
To jig-tailings stockpile
To tailings pond
Automatic sampler

FIGURE 5. - Flowsheet of Concentrating Plant.

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Jigs

Ore from the 275-ton jig feedbin is conveyed by a 20-inch belt conveyor to a 20-inch bucket elevator, which empties into a drag conveyor. The drag conveyor discharges into the jig feedbox, where the feed is split equally between two 36- by 42-inch, 4-compartment, Harz-type jigs. Each jig is operated at 108 strokes per minute by individual motor drives through gear reducers with sprocket and chain drives.

The hutch and the cup discharges from the first cell of each jig are combined to make a lead concentrate, which is delivered by a bucket elevator to a four-cell Harz-type cleaner jig. The continuous discharge from the last 3 cups of the rougher jigs, together with the hutch, locally called smittem, flows by gravity to the 4- by 36-foot master drag classifier for dewatering. The dewatered product is discharged onto a 20-inch bucket elevator, which empties into the 100-ton smittem bin.

Overflow from the rougher jigs goes to a 4.0- by 21.5-foot dewatering drag. Sands from the drag are delivered by a bucket elevator to a tailings stockpile. Overflow from the drag goes to the 50-foot thickener.

The lead-cleaner jig is a 4-compartment, 36- by 42-inch, Harz-type jig; only the first 2 compartments are used. This jig, which operates at 150 strokes per minute, produces a finished lead concentrate from the cups of both cells and the hutch from the first cell, which is then combined with the tabled flotation concentrate for shipment to the smelter. Hutch from the second cell is returned to the lead-concentrate elevator. Tailings from the lead-cleaner jig are discharged by gravity to the master drag.

Fine Grinding

Flotation feed containing about 15.0 percent zinc and 0.5 percent lead is mechanically drawn from the smittem bin onto a 20-inch belt conveyor, which discharges onto a bucket elevator that empties into the ball-mill feedbox. The operator controls the feed rate from the smittem bin by weighing the ore on the belt; 6 pounds per foot is equivalent to 5.64 tons per hour. Feed is normally maintained at 8 to 10 tons per hour.

The underflow from the thickener is pumped into the feedbox by a 4-inch Dagley, suction-pressure diaphragm pump. Also, sands from the cone flow by gravity to the feed box. The ball mill, a 6- by 6-foot Traylor driven by a 100-horsepower motor, is operated in closed circuit with a Denver sub-A cell and a 36-inch by 21-1/2-foot Wemco spiral classifier driven by a 3-horsepower motor. Concentrates from the sub-A cell go to the 3- by 3-inch SRL pump, which feeds the 2-inch Dorrclone.

Flotation

Overflow from the Wemco classifier of approximately 25.0 percent solids and 85.0 percent minus-65-mesh is pumped by a 3-inch Wilfley pump to a 5- by 5-foot Denver conditioner, which discharges by gravity to a 4-cell section of a No. 21 Denver sub-A flotation machine, driven by two 7-1/2-horsepower motors.

A low-grade lead concentrate is removed here and, along with the concentrates from the sub-A cell, pumped by a 3- by 3-inch SRL pump to a 2-inch Dorrclone. Sands from the Dorrclone are discharged to a standard-deck Butchart concentrating table for removing a finished lead concentrate. This product is decanted and mixed with the lead concentrates from the jigs. Overflow from the Dorrclone is returned to the master drag along with tailings from the table.

The tailing from the lead-flotation cells flows by gravity to a 5- by 5-foot Denver conditioner, which discharges to the zinc-flotation section - a 12-cell bank of No. 21 Denver flotation machines, driven by four 10-horsepower motors. The feed enters cell 3. Concentrates from cells 3 and 4 go to cell 1 for cleaning in cells 1 and 2; concentrates from cells 5, 6, 7, and 8 are returned to cell 4; and concentrates from cells 9, 10, 11, and 12 are returned to cell 8. The final tailings are discharged from cell 12.

Zinc concentrates are drawn from cell 2 and pumped by a 4-inch Dagley, suction-diaphragm pump to a 6-foot, American-type filter. The filter originally had 4 disks, but 2 are enough for the amount of concentrates being filtered. The filter cake contains 9 percent moisture.

Tailings from the zinc-flotation machine pass through an automatic sampler and can be diverted either directly to the tailings pond or to a 3-inch Wilfley pump for discharge on the jig-tailings stockpile. Overflow from the Dorr thickener goes to the mill pond.

Reagents

Reagent 242 (a neutralized, phosphorus pentasulfide) and sodium cyanide are added to the ball mill. No lime is added; pH is 7.5 in the lead circuit.

Copper sulfate and lime are added to the conditioner ahead of the zinc circuit. Sodium aerofloat is used as the collector and added to the conditioner overflow along with frother 70, one of the higher alcohol frothers. A pH of 8.5 to 9.0 is maintained in the zinc circuit. Reagent consumption in August 1956 was:

	Pounds per ton of mill feed
NaCN	0.14
$CuSO_4$	1.41
$CaCO_3$	2.21
Reagent 242	.12
NaAF	.05
Frother 70	.10

Disposal of Tailings

Jig tailings are mixed with about 50 percent of the flotation tailings and stacked about 60 feet from the mill building to a height of 40 feet with an inclined conveyor.

Flotation tailings are stored in the conventional manner by utilizing the sands to build a tailings dam and settling pond in which the water is clarified for reuse in the mill or discharged into the natural drainage.

Water Supply

Water is supplied by an 8-inch Pomona, deep-well pump in an old mine shaft, 107 feet deep, about 500 feet from the mill. Water is pumped at the rate of 600 gallons per minute through a 10-inch steel pipe to the tailings pond below the mill.

An 8-inch Gould centrifugal pump, of 1,200-gallon-per-minute capacity, supplies water for mill operations. The intake to the pump from the pond is so far below water level that freezing during winter does not cut off the water supply to the mill.

Metallurgy

The average mill feed contains 5.5 percent zinc and 0.5 percent lead. Available data indicated that jig operation eliminates about 50 percent of the original feed as a final tail and upgrades the zinc content to about 11.0 percent. The jigs recover 90 percent of the lead in concentrate containing 75 percent lead. Only 2 percent of the lead in the mill feed is removed by flotation and tabling, but the additional processing is necessary to insure a premium-grade zinc concentrate.

Zinc sulfide recoveries are estimated to be as high as 92 percent, but the total zinc recovery is about 2 percent less, owing to the loss of zinc carbonate, which does not float. Zinc concentrate shipped averages 62 percent zinc content.

MARKETING

Both the lead and zinc concentrates are hauled about 4 miles by truck to Potosi, Wis., a station on the Chicago, Burlington & Quincy Railroad. Concentrates are loaded into boxcars with a small end loader. Sales are made through the Metal and Ore Department of the American Zinc Co. of Illinois. Usually the zinc concentrate is shipped to Matthiessen and Hegler at LaSalle, Ill., and the lead concentrate to the American Smelting and Refining Co. smelter at Federal, Ill.

Tailings from the jig mill are sold locally, as they make excellent top dressing for roads. Adding some flotation tailings to the jig rejects acts as a binder and improves the material for this use.

SAFETY

Because the operation is small, no formal safety program is conducted. First-aid stations are maintained at the mine and the mill. Regular periodic inspections are made by the State mine inspector and by the insurance company that carries the compensation insurance for the mine. Both inspectors test the air, and all their recommendations are followed.

LABOR

No contract or bonus system is used. The labor force is recruited locally and trained on the job. Employees commute from the surrounding area by automobile. Because the operation is small, management and labor have been on a very high level of friendliness and understanding.

The mine operates two shifts. Drilling and blasting are done on the night shift, and all loading and occasionally some drilling are done on the day shift.

The pay scale ranges from $1.50 to $2.15 per hour in the mill and from $1.65 to $2.05 per hour in the mine.

The total labor force is as follows:

Mine:	
Drillers	4
Powderman	1
Trimmers	2
Truck drivers	4
Shovel operator	1
Foreman	1
Total	13
Mill:	
Crusher operator	1
Jig operators	2
Flotation operators	3
Flotation helpers	3
Superintendent	1
Total	10
Surface:	
Shop foreman	1
Electrician	1
Mechanic	1
Office	2
General manager	1
Total	6
Total mine, mill, and surface	29

PERFORMANCE DATA

At the time of the examination (October 1956) the mine and mill had only been in operation a little over a year, hence the performance figures were affected to a considerable extent by the delays and adjustments that occurred during the shakedown period. Table 2 shows the relative costs of different operations as a percentage of the total mining and milling cost.

TABLE 2. - Performance data in percentage of total cost

	Percent of total cost
Mining cost:	
Breaking	27.8
Loading	3.7
Hauling	7.9
Development and miscellaneous[1]	2.6
Total	42.0
Milling cost:	
Crushing	2.6
Jigging	2.9
Grinding and flotation	15.3
Other mill expense[2]	16.2
Total	37.0
Administrative and general[3]	21.0
Grand total	100.0

[1] Development and miscellaneous includes cost of surface churn drilling during mining operations.

[2] Includes tailings disposal.

[3] Administrative and general expense includes mine superintendent, clerical and office expense, heating, rentals, communication services, travel, contributions, engineering and legal expense, insurance, social security, taxes, and royalty.